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NPOESS: *Monitoring the Near-Earth Space Environment*

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NPOESS: Monitoring the Near-Earth Space Environment

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This is the ninth in a series of articles on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). In previous articles, we described NPOESS and its capabilities to monitor and observe land, sea, and air to improve forecasts of "terrestrial weather" and Earth's environment. NPOESS will also carry a suite of sensors designed to monitor the near-Earth space environment. Measurements from these sensors will improve our capability to observe and forecast "space weather" and mitigate its effects on space- and ground-based technological systems and manned spaceflight missions.

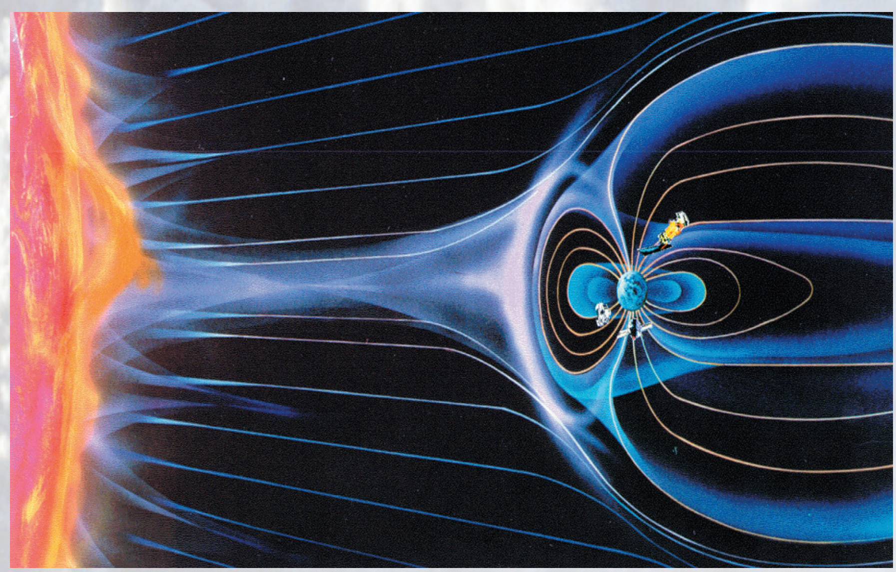


Illustration of Sun-Earth connections. The Sun drives our weather here on Earth and also emits huge amounts of energy that could affect satellites orbiting as well as sensitive ground systems such as power grids and mobile phone networks. (Image not to scale.)

Introduction: Forecasting the Future

Imagine the year 2018. It is a busy day on the International Space Station as the mission astronauts prepare to launch a trans-lunar shuttle to a construction site, Mare Tranquillitatis. Suddenly, the space environmental warning system blares a message, *"WARNING! A solar X-Ray event has been detected. All personnel report immediately to radiation shelters."*

The space-based X-Ray telescopes on the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellites (GOES) and ground-based optical and radio telescopes operated by the United States Air Force (USAF) have just detected an extremely powerful solar flare on the face of the Sun.

Moments later as the space station crew members settle into their protective shelters, high-energy protons are detected by the space environmental sensors on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). Using these data, space weather forecasters at NOAA's Space Environment Center relay a message through the National Aeronautics and Space Administration (NASA) that the radiation storm will decay to safe levels within an hour. Meanwhile, Air Force Weather personnel are advising military satellite operators that navigational errors and communication disruptions can be expected and that predetermined backup procedures should be implemented to avoid adverse impacts to deployed forces and military operations. Satellite operators are now able to identify spacecraft malfunctions as being associated with adverse space weather conditions rather than hostile actions against their systems, analogous to a space-aged "Pearl Harbor" attack.

Science Fiction or a Real Future Possibility?

In fact, space weather does impact today's highly-complex technological systems and we've begun to operationally monitor daily variations in space weather through a wide range of ground-based and space-based sensors.

No, this is not an artist's rendition. It is the northern lights over Svalbard, Norway, which is a prime location for the reception of satellite data and imagery in the northern latitudes. Solar storms sometimes cause shimmering, often colorful lights, called auroras, to appear in the night skies. Auroras usually appear in the northern latitudes but occasionally can be seen from points further south. Image courtesy: B. Hillestad, Kongsberg Satellite Services (KSAT).

Recent examples show just how vulnerable we are to space weather.

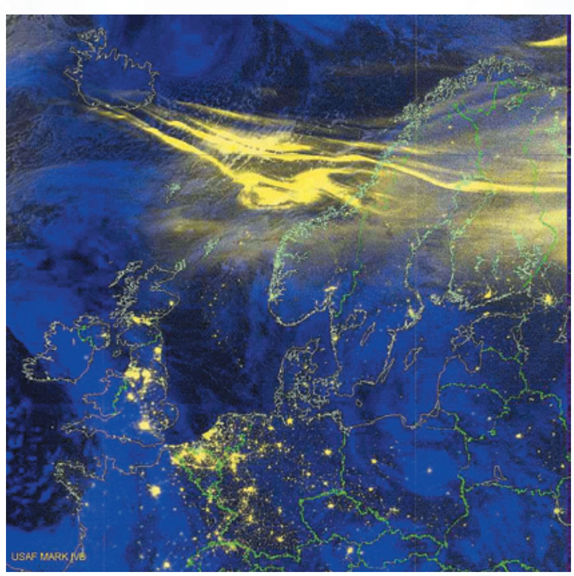
In October 2003, a series of large geomagnetic storms caused numerous problems in the near-Earth space environment and around the world. These solar storms forced trans-polar commercial airliners to divert to more southerly routes to reduce hazards to passengers and crew and to avoid High Frequency (HF) communication losses. The electrical power grid in southern Sweden tripped, plunging the city of Malmo and its population of over 250,000 into darkness. At the same time, numerous near-Earth spacecraft suffered service disruptions, component damage, or complete mission failure, as was the case for the ADvanced Earth Observing Satellite 2 (ADEOS-2) also known as Midori-2. In January 1997, a similar geomagnetic storm severely damaged the U.S. Telstar 401 communication satellite, which was valued at $200 million, and left it inoperable.

In years past, space weather was identified as the culprit in many system failures and disruptions. In 1989, Hydro-Quebec suffered an extensive power outage caused by a severe geomagnetic storm that destroyed portions of the Canadian electric power distribution system and left 6 million people without electricity for 9 hours at an estimated cost of $300 million. The direct financial impact to Hydro-Quebec from this storm alone was estimated to be in excess of $10 million dollars.

Space weather is a real, certainly costly, and potentially life threatening phenomenon. The National Space Weather Program (NSWP) describes space weather as the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can increase human risk to radiation exposure in high altitude aircraft and on manned spaceflight missions, disrupt satellite operations, impact the communication and navigational infrastructure, and damage electric power distribution grids, leading to a variety of socioeconomic losses. The NSWP, overseen by the Federal Coordinator for Meteorology, is responsible for implementing a national strategy to advance the observation of and response to adverse space weather and to prevent or mitigate the deleterious effects of space weather events. The goal of the program is to achieve an interagency system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts within the next ten years.

NPOESS Space Environmental Sensor Suite

So what is being done to mitigate the effects of space weather? NPOESS is at the forefront, among the many space-based and ground-based sensors currently deployed and being developed. NPOESS will advance near-Earth space environmental sensing capabilities and deliver critical observations to space weather forecasters in NOAA and the USAF faster than ever before. New technologies from the research community will be incorporated into NPOESS under a program for Pre-Planned Product Improvement (P3I). NPOESS will provide improved operational capabilities beyond those currently available from the Department of Defense's (DoD) Defense Meteorological Satellite Program (DMSP)



An intense aurora over Norway and Sweden on October 30, 2003 as seen from the Defense Meteorological Satellite, which will be replaced by NPOESS in 2009. Space weather observation is an important role for NPOESS as key parts of our nation's infrastructure are vulnerable to solar storms.

and NOAA's Polar-orbiting Operational Environmental Satellite (POES) systems that NPOESS will replace.

NPOESS will expand the ranges and sensitivities of the DMSP and POES sensors for monitoring the near-Earth space environment. Currently, DMSP and POES satellites measure the space environment in the vicinity of the spacecraft using a variety of sensor technologies. An ionospheric cold plasma sensor, auroral ion and electron spectrometers, and a magnetometer are deployed on each DMSP spacecraft. Sensors aboard NOAA's POES spacecraft measure the differential flux of ions and electrons over a wide energy range.

DMSP also carries ultraviolet (UV) remote sensing instruments for broad-area observations of charged and neutral particle densities within the atmosphere. Instruments comprising the Space Environmental Sensor Suite (SESS) will be included in each of the three NPOESS orbits. These evenly spaced, sun-synchronous orbits will provide global coverage every four hours, with increased spatial and temporal resolution that will provide significant improvements over current capabilities.

Within the space environment, the NPOESS SESS will provide measurements needed to satisfy user requirements for 11 Environmental Data Records (EDRs), including specifications of the ionosphere and neutral atmosphere, measurements of energetic charged particles, and the morphology of the high-latitude aurora. Similar to the instruments on DMSP and POES, the SESS will rely on a combination of *in situ* and remote sensing techniques to measure the assigned set of space environment EDRs.

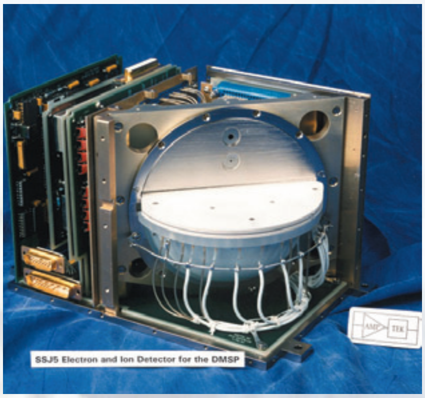
- The Thermal Plasma Sensor (TPS) will monitor the temperature, density, and motion of the local ionosphere at the 828-km altitude of the NPOESS satellite.
- A complement of particle detectors will measure the flux and energy of charged particle precipitation into the atmosphere along magnetic field lines that trace to distant space.
- Precipitating charged particles ranging in energy from 30 electron volts (eV) to over 100 million eV will be measured within three distinct energy bands by the Low Energy Particle Sensor (LEPS), the Medium Energy Particle Sensor (MEPS), and the High Energy Particle Sensor (HEPS).
- Remote optical imagery of UV emissions measured by the UV-Limb/Disk Imager will be used to determine the density profiles of the ionosphere and thermosphere.
- UV-Limb/Disk Imager data with supporting measurements from the NPOESS Visible/Infrared Imager Radiometer Suite (VIIRS) will be used to measure the auroral energy-deposition rates. When fused with ancillary data from other NPOESS sensors, the space environmental measurements from SESS will better meet user needs for near-Earth space environmental data.

NPOESS is also seeking innovative approaches to address other space environment EDRs, such as measuring the geomagnetic field using data from other, more suitable, spacecraft and employing the NPOESS infrastructure to bring these observations to users.

A revolutionary improvement in data retrieval is planned for NPOESS. The SafetyNet™ ground data receptor network will enable users to receive and process NPOESS environmental data in less than 28 minutes for 95% of the data compared to about two hours for the DMSP and POES systems. Considering that space environmental conditions can vary on time scales of tens of minutes, SafetyNet™ will allow space weather service providers to better support time-critical operations and space-based resource protection.

Preparing for the Future

Although the NPOESS space environment sensors will be quite capable, there is a need for improved measurements. In fact, thanks in part to the active participation of the future NPOESS users, planned NPOESS SESS capabilities have already improved some 40% over the original design. The developers of NPOESS are keenly aware that even the best sensors are of little use unless the science is adequate to yield efficient and reliable algorithms to convert raw data into useable environmental products. To this end, the NPOESS prime contractor (Northrop Grumman Space Technology), the NPOESS Integrated Program Office (IPO), and the scientific community participate in Operational Algorithm Teams (OATs).

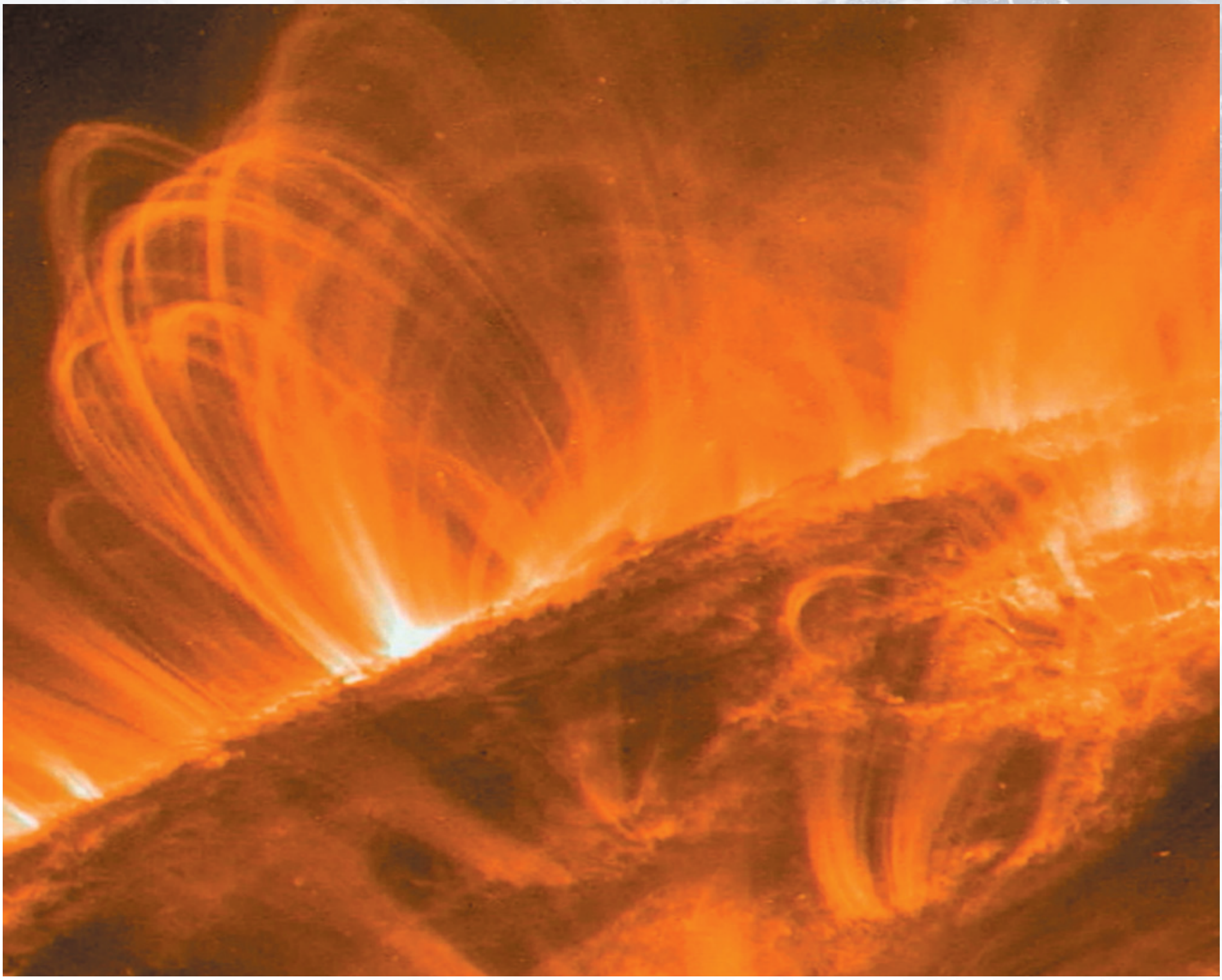


DMSP energetic particle sensor (SSJ5). The SSJ5 is the heritage sensor for the NPOESS LEPS (Low Energy Particle Sensor).

The NPOESS P3I program, previously discussed, will also address shortfalls in user needs, including requirements for measuring ionospheric scintillation. Ionospheric scintillation is among the military's top space weather concerns due to the potential degradation of Ultra High Frequency (UHF) communications and Global Positioning System (GPS) navigation. The NPOESS IPO is working closely with the user community, the research community, and industry to insert the latest capabilities into NPOESS to meet validated user needs.

NPOESS will carry on a long legacy of operational space-based measurements of the space environment. As the civilian and military sectors continue to expand their reliance on space it will become imperative that our monitoring, analysis, and forecasting tools for space weather improve to meet our increased needs.

NPOESS will become a key component of our national strategy for space weather. The active involvement of the user community is critical to NPOESS and will allow the program to meet near-term operational requirements and be poised to meet future needs. The seemingly science fiction of today will be the science fact of tomorrow when it comes to space weather. A developing space weather monitor-and-alert system will indeed help us to live a safer and more efficient life on planet Earth.



Fountains of multimillion-degree, electrified gas in the atmosphere of the Sun have revealed the location where the solar atmosphere is heated to temperatures 300 times greater than the Sun's visible surface. Image courtesy: NASA TRACE (Transition Region and Coronal Explorer) spacecraft.

NPOESS' capabilities to sense the space environment will benefit numerous communities, in particular industry, the military, the communications sector, and the public. NPOESS terrestrial weather observations will bring great advantages to the other socioeconomic sectors as well. In the next article in this series we'll explore how NPOESS will help feed and further protect the passengers of "spaceship earth."

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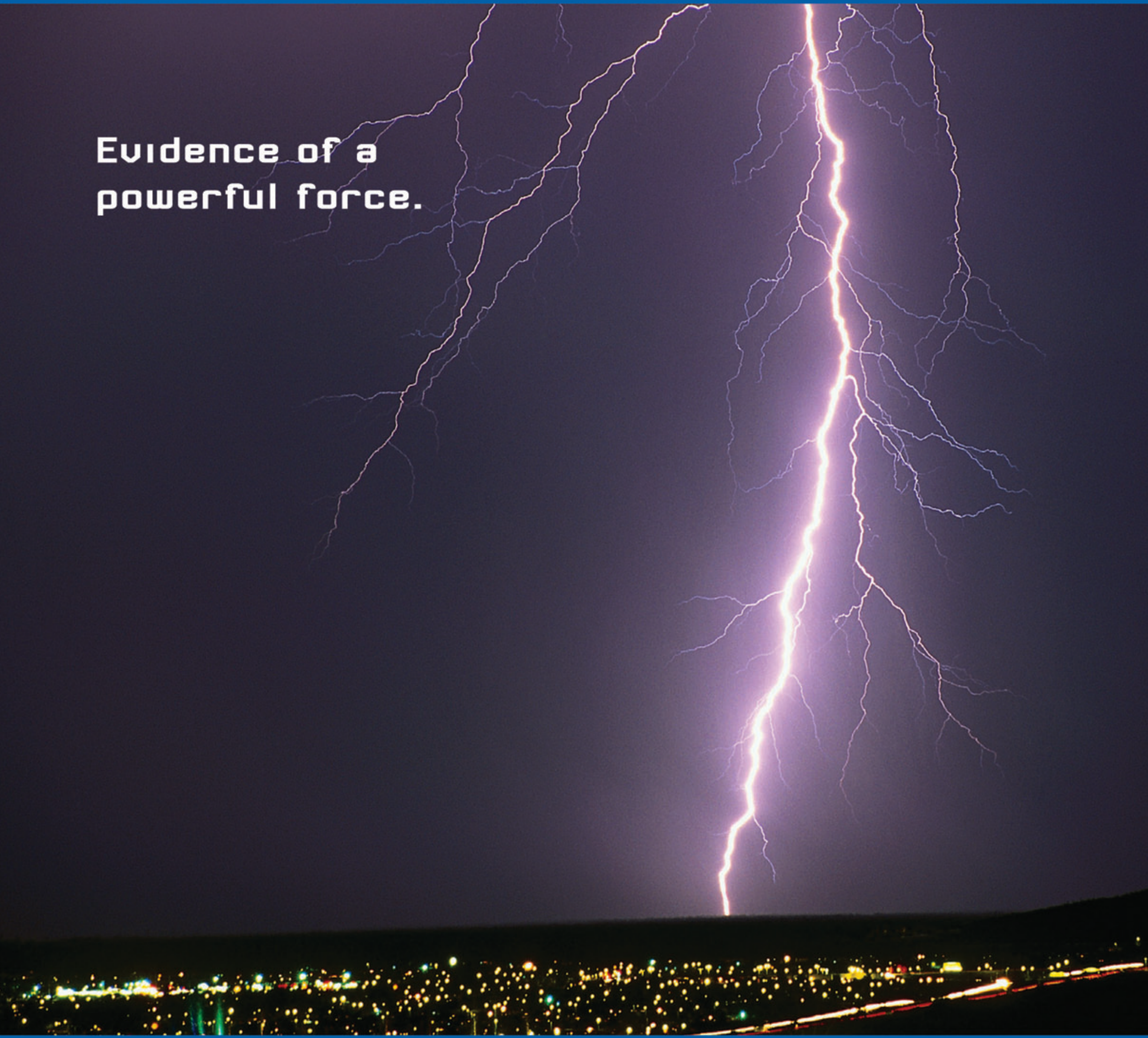

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